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DESCRIPTION

BOUNDARY ACOUSTIC WAVE DEVICE

Technical Field

The present invention relates to a boundary acoustic wave device using a boundary acoustic wave which propagates along a boundary between a first medium layer and a second medium layer having a different sound velocity therefrom, and more particularly, relates to a boundary acoustic wave device having the structure to suppress unwanted spurious signals.

Background Art

In surface acoustic wave devices using a surface acoustic wave such as a Rayleigh wave or a first leakage wave, miniaturization and reduction in weight can be achieved, and in addition, the adjustment is not required.

Hence, the surface acoustic wave devices have been widely used for RF or IF filters in mobile phones, VCO resonators, or VIF filters for televisions.

However, since having properties propagating along a surface of a medium, a surface acoustic wave is sensitive to the change in surface condition of the medium. Accordingly, in a chip through which a surface acoustic wave propagates,

a chip surface along which a surface acoustic wave propagates must be protected. Hence, a surface acoustic wave device must be hermetic-sealed using a package having a cavity portion therein so that the chip surface of the surface acoustic wave chip faces the cavity portion. As a result, the cost of the package as described above is generally high, and in addition, the size of the package becomes inevitably much larger than that of the surface acoustic wave chip.

As a device which does not require the package having a cavity portion as described above, a boundary acoustic wave device has been proposed.

Fig. 15 is a front cross-sectional view and a schematic perspective view showing one example of a conventional boundary acoustic wave device. In a boundary acoustic wave device 101, a first medium layer 102 and a second medium layer 103 having a different sound velocity therefrom are laminated to each other. At a boundary A between the first medium layer 102 and the second medium layer 103, an IDT 104 functioning as an electroacoustic transducer is disposed. In addition, at the two sides of the IDT 104 in the direction along which a boundary acoustic wave propagates, reflectors (not shown) are disposed.

In the boundary acoustic wave device 101, by applying an input signal to the IDT 104, a boundary acoustic wave is

driven. The boundary acoustic wave propagates along the boundary A of the boundary acoustic wave device 101 as schematically shown by an arrow B in Fig. 15.

In "Piezoelectric Acoustic Boundary Waves Propagating Along the Interface Between SiO_2 and $LiTaO_3$" IEEE Trans. Sonics and ultrason., VOL. SU-25, No. 6, 1978 IEEE, one example of the boundary acoustic wave device as described above has been disclosed. In this device, an IDT is formed on a 126° rotated Y plate X propagating $LiTaO_3$ substrate, and a SiO_2 film having a predetermined thickness is formed on the $LiTaO_3$ substrate so as to cover the IDT. In this structure, it has been disclosed that an SV+P type boundary acoustic wave, a so-called Stoneley wave, propagates. In "Piezoelectric Acoustic Boundary Waves Propagating Along the Interface Between SiO_2 and $LiTaO_3$" IEEE Trans. Sonics and ultrason., VOL. SU-25, No. 6, 1978 IEEE, it has been disclosed that when the thickness of the SiO_2 film is set to 1.0 λ (λ indicates the wavelength of a boundary acoustic wave), an electromechanical coefficient of 2% is obtained.

In addition, in "Highly Piezoelectric Boundary Acoustic Wave Propagating in $Si/SiO_2/LiNbO_3$ Structure" (26th EM symposium, May 1997, pp. 53 to 58), an SH type boundary acoustic wave has been disclosed propagating in a [001]-Si<110>/SiO_2/Y-cut X propagating $LiNbO_3$ structure. This SH type boundary acoustic wave has an advantage in that an

electromechanical coefficient k^2 is large as compared to that of the Stoneley wave. In addition, since the SH type boundary acoustic wave is an SH type wave, it is expected that the reflection coefficient of electrode fingers forming an IDT reflector is large as compared to that in the case of the Stoneley wave. Hence, when a resonator or a resonator type filter is formed by using the SH type boundary acoustic wave, miniaturization can be further achieved, and in addition, it is also expected that steeper frequency properties can be obtained.

Since the boundary acoustic wave devices use a boundary acoustic wave, which are disclosed in "Piezoelectric Acoustic Boundary Waves Propagating Along the Interface Between SiO_2 and $LiTaO_3$" IEEE Trans. Sonics and ultrason., VOL. SU-25, No. 6, 1978 IEEE and "Highly Piezoelectric Boundary Acoustic Wave Propagating in $Si/SiO_2/LiNbO_3$ Structure" (26th EM symposium, May 1997, pp. 53 to 58), a package having a cavity portion is not required. Hence, miniaturization of acoustic wave devices and cost reduction thereof can be achieved. However, it was first found through experiments carried out by the inventors of the present invention that, when the boundary acoustic wave device is actually formed, a problem of frequency properties occurs in that unwanted spurious signals are liable to be generated.

Figs. 16 and 17 are views illustrating a problem of a conventional boundary acoustic wave device, Fig. 16 is a schematic perspective view showing the appearance of the boundary acoustic wave device, and Fig. 17 is a view showing the frequency properties thereof.

As shown in Fig. 16, on a Y-cut X propagating single crystal $LiNbO_3$ substrate 112, an IDT 113 and reflectors 114 and 115 are formed using a Au film having a thickness of 0.05 λ. In addition, on the single crystal $LiNbO_3$ substrate 112, a SiO_2 film 116 having a thickness of 3.3 λ is formed by RF magnetron sputtering at a wafer heating temperature of 200°C so as to cover the IDT 113 and the reflectors 114 and 115. The number of electrode finger pairs of the IDT 113, the cross width, and the duty ratio of the electrode finger are set to 50 pairs, 30 λ, and 0.6, respectively. In addition, the number of the electrode fingers of the reflectors 114 and 115 are each set to 50, and λ of the reflectors 114 and 115 are set to coincide with the wavelength λ of the IDT 113. In addition, the distances between the center of the electrode finger of the IDT 113 and that of the reflectors 114 and 115 are each set to 0.5 λ. On the upper and the lower sides of the Au film, thin Ti layers are formed by deposition in order to enhance the adhesion.

The frequency properties of a boundary acoustic wave

device 111 formed as described above are shown in Fig. 17. As can be seen from Fig. 17, in the boundary acoustic wave device 111, a plurality of spurious signals having certain intensity is generated at a higher frequency side than that at an anti-resonance frequency and the vicinity thereof.

Accordingly, when the boundary acoustic wave device 111 is used as a resonator, unnecessary resonance is generated by the spurious signals described above, and in addition, when the boundary acoustic wave device 111 is used as a filter, the out-band suppression level is degraded thereby; hence, it is understood that the spurious signals heavily interferers with the production of practical boundary acoustic wave devices.

Disclosure of Invention

In consideration of the conventional techniques described above, an object of the present invention is to provide a boundary acoustic wave device which can effectively suppress unwanted spurious signals and can obtain superior frequency properties.

In accordance with a first aspect of the present invention, there is provided a boundary acoustic wave device using a boundary acoustic wave which propagates along a boundary between a first medium layer and a second medium layer, in which the sound velocity of the second medium

layer is low as compared to that of the first medium layer, and when the wavelength of the boundary acoustic wave is represented by λ, the thickness of the second medium layer is set to 7 λ or more. That is, according to the first aspect of the present invention, since the second medium layer having a low relatively sound velocity is formed to have a specific thickness, unwanted spurious signals can be effectively suppressed.

In accordance with a second aspect of the present invention, there is provided a boundary acoustic wave device using a boundary acoustic wave which propagates along a boundary surface between a first medium layer and a second medium layer, in which a structure for scattering an acoustic wave is provided for at least one surface of the first and/or the second medium layer at the side opposite to the boundary surface therebetween.

In the second aspect of the present invention, since the structure for scattering an acoustic wave is provided, unwanted spurious signals can be suppressed.

According to one specific case of the second aspect of the present invention, the sound velocity of the second medium layer is low as compared to that of the first medium layer, and the structure for scattering an acoustic wave is provided for the second medium layer.

According to another specific case of the second aspect

of the present invention, the structure for scattering an acoustic wave is at least one recess portion and/or at least one protrusion portion provided for at least one surface of the medium layers at the side opposite to the boundary surface.

According to another specific case of the second aspect of the present invention, when the wavelength of the boundary acoustic wave is represented by λ, the depth of the recess portion or the height of the protrusion portion is 0.05 λ or more.

According to another specific case of the second aspect of the present invention, when the wavelength of the boundary acoustic wave is represented by λ, the pitch between the recess portions and/or the pitch between the protrusion portions is 1 λ or more.

According to another specific case of the second aspect of the present invention, when the wavelength of the boundary acoustic wave is represented by λ, the thickness of the medium layer for which the structure for scattering an acoustic wave is provided is 7 λ or less, the thickness of the medium layer being the distance between the boundary surface and the surface opposite thereto. That is, when the thickness of the first medium layer having a low sound velocity is less than 7 λ, it is difficult to suppress the spurious signals; however, when the structure for scattering

an acoustic wave is used, the spurious signals can be suppressed.

According to another specific case of the second aspect of the present invention, the second medium layer is composed of SiO_2, the first medium layer is composed of a piezoelectric substrate containing Li, and at least one recess portion and/or at least one protrusion portion is formed on a surface of the second medium layer composed of SiO_2.

According to a specific case of the first and the second aspects of the present invention, an electroacoustic transducer for driving a boundary acoustic wave is formed between the first and the second medium layers.

According to another specific case of the first and the second aspects of the present invention, at least one reflector is further provided at the boundary between the first medium layer and the second medium layer.

According to another specific case of the second aspect of the present invention, an exterior layer material is further provided on the surface of the medium layer on which at least one recess portion and/or at least one protrusion portion is provided.

Brief Description of the Drawings

Figs. 1(a) and 1(b) are a schematic front cross-

sectional view showing an important portion of a boundary acoustic wave device of a first embodiment of the present invention and a schematic perspective view showing the appearance thereof, respectively.

Fig. 2 is a view showing a displacement distribution of a main mode of a boundary acoustic wave in conventional boundary acoustic wave devices shown in Figs. 15 and 16.

Fig. 3 is a view showing one example of a displacement distribution of a spurious mode under the same conditions shown in Fig. 2.

Fig. 4 is a view showing one example of a displacement distribution of a spurious mode under the same conditions shown in Fig. 2.

Fig. 5 is a view showing one example of a displacement distribution of a spurious mode under the same conditions shown in Fig. 2.

Fig. 6 is a view showing one example of a displacement distribution of a spurious mode under the same conditions shown in Fig. 2.

Fig. 7 is a view showing one example of a displacement distribution of a spurious mode under the same conditions shown in Fig. 2.

Fig. 8 is a view showing one example of a displacement distribution of a spurious mode under the same conditions shown in Fig. 2.

Fig. 9 is a view showing impedance properties of the boundary acoustic wave device of the first embodiment.

Fig. 10 is a view showing the change in impedance ratio of a spurious mode obtained when the depth of grooves forming irregularities in the first embodiment is changed.

Fig. 11 is a view showing the change in impedance ratio of a spurious mode obtained when the pitch between grooves forming irregularities is changed.

Fig. 12 is a schematic perspective view illustrating the structure of grooves of a modified example of the boundary acoustic wave device of the first embodiment.

Fig. 13 is a view illustrating a second embodiment of the present invention and is a view showing the change in impedance ratio of a spurious mode obtained when the thickness of a SiO_2 film having a relatively low sound velocity is changed.

Fig. 14 is a schematic partial front cross-sectional view showing an important portion of a boundary acoustic wave device of a modified example of the boundary acoustic wave device of the first embodiment.

Fig. 15 is a schematic partially cut-away front cross-sectional view illustrating a conventional boundary acoustic wave device.

Fig. 16 is a schematic perspective view illustrating a conventional boundary acoustic wave device.

Fig. 17 is a view showing impedance properties of the boundary acoustic wave device shown in Fig. 16.

Best Mode for Carrying Out the Invention

Hereinafter, with reference to figures, particular embodiments of the present invention will be described so that the present invention will be clearly understood.

First, in order to investigate the causes of the spurious signals shown in Fig. 17, the numerical analysis of the boundary acoustic wave device 111 shown in Fig. 16 is performed, so that the displacement distribution of a boundary acoustic wave and the displacement distribution of a spurious mode are obtained. In this investigation, it is assumed that the displacement between a SiO_2 film and Au and that between the Au and a $LiNbO_3$ substrate are continuous and the stress in the vertical direction is continuous, the potential is 0 because of a short-circuiting boundary, the SiO_2 film has a predetermined thickness, and the $LiNbO_3$ has an infinite thickness.

Fig. 2 shows the displacement distribution of a main mode of a boundary acoustic wave when the thickness of the SiO_2 film is set to 2.5 λ, and Figs. 3 to 8 show the displacement distributions of respective spurious modes under the same conditions as above. In Figs. 2 to 8, U_1, U_2, and U_3 represent a P wave component, an SH wave component,

and an SV component, respectively, the horizontal axis indicates the displacement normalized by the maximum value, and the vertical axis indicates the depth direction (- side is the lower side).

As can be seen from Fig. 2, it is understood that the main mode of the boundary acoustic wave is an SH type boundary acoustic wave which is primarily composed of an SH type component. In addition, from Figs. 3 to 8, it is understood that the spurious mode can be roughly categorized into two types of modes; one spurious mode is primarily composed of an SH wave component, and the other spurious mode is primarily composed of a P wave and an SV wave component. The two types of spurious modes propagate along the upper surface of the SiO_2 film and along the boundary between the SiO_2 film and an IDT which is made of Au. In addition, it is believed that since a plurality of high-order modes of the above two types of spurious modes is generated, many spurious signals are generated as shown in Fig. 17.

The boundary acoustic wave device of the present invention was developed in order to achieve the suppression of the spurious signals as described above.

(First Embodiment)

Figs. 1(a) and 1(b) are a schematic front cross-sectional view and a schematic perspective view,

respectively, illustrating a first embodiment of a boundary acoustic wave device of the present invention.

In a boundary acoustic wave device 1, a first medium layer 2 and a second medium layer 3 are laminated to each other. In this embodiment, the first medium layer 2 is formed of a Y-cut X propagating single crystal $LiNbO_3$ substrate, and the second medium layer 3 is formed of a SiO_2 film. Between the single crystal $LiNbO_3$ substrate 2 and the SiO_2 film 3, that is, at a boundary A between the first and the second medium layers, an IDT 4 as an electroacoustic transducer is disposed. In Fig. 1(a), a part at which the IDT 4 is disposed is only shown; however, as shown in Fig. 1(b), grating type reflectors 5 and 6 are provided at two sides of the IDT 4 in the direction along which a boundary acoustic wave propagates. A film of Au having a thickness of 0.05 λ is formed on the single crystal $LiNbO_3$ substrate 2, so that the IDT 4 and the reflectors 5 and 6 are formed.

In addition, after the IDT 4 and the reflectors 5 and 6 are formed, a SiO_2 film having a thickness of 3.0 λ is formed at a wafer heating temperature of 200°C by RF magnetron sputtering, thereby forming the SiO_2 film 3.

The number of electrode finger pairs of the IDT 4, the cross width, and the duty ratio of the electrode finger forming the IDT 4 are set to 50 pairs, 30 λ, and 0.6, respectively. The number of the electrode fingers of the

reflectors 5 and 6 are set to 50, and wavelengths λ of the IDT 4 and the reflectors 5 and 6 are set to coincide with each other. In addition, the distances between the IDT and the reflectors are each set to 0.5 λ as the distance between the centers of the electrode fingers.

In order to enhance the adhesion, on the upper and the lower sides of the Au film, thin Ti films having a thickness of approximately 0.0005 λ are formed by deposition.

Next, in an upper surface 3a of the SiO_2 film 3, a plurality of grooves 3b having a depth of 1 μm is formed by machining to have an angle of 30° with respect to the direction in which the electrode fingers of the IDT 4 extend, so that the boundary acoustic wave device 1 of this embodiment is obtained.

The impedance properties of the boundary acoustic wave device 1 thus obtained are shown in Fig. 9.

As can be clearly seen when Fig. 9 is compared with the impedance properties of the boundary acoustic wave device 111 shown in Fig. 17, it is understood that the plurality of spurious responses present at a higher frequency side than that at the anti-resonance frequency is suppressed in this embodiment. For example, when a spurious signal generated at 1,300 MHz is represented by an impedance ratio, which is a ratio of the impedance at the resonance frequency to that at the anti-resonance frequency, it is understood that the

spurious signal can be suppressed from 22.9 dB to 6.6 dB, that is, can be suppressed to one third.

The feature of the boundary acoustic wave device 1 of this embodiment is that, as described above, the grooves 3b are formed in the upper surface 3a of the SiO_2 film 3, which is located opposite to the boundary surface A, so as to form recess portions. It is believed that by the formation of the recess portions, the spurious mode is scattered, and that the spurious signals are suppressed thereby as described above.

In consideration of the results obtained from the above boundary acoustic wave device 1, the inventors of the present invention carried out further investigation in the depth of the recess portion and the shape thereof.

In the same way as described above, the boundary acoustic wave device 1 was formed. However, when the recess portions were formed in the upper surface of the SiO_2 film 3, the grooves 3b were formed so as to have an angle of 45° with respect to the direction in which the electrode fingers of the IDT 4 extended, the grooves 3b being obtained by forming a resist pattern on the SiO_2 film 3 using a photolithographic step, followed by wet etching with a diluted hydrogen fluoride solution. By the change in resist pattern, the change in etching conditions, and the like, the depth of the grooves 3b and the pitch therebetween were

variously changed, so that a plurality types of boundary acoustic wave devices was obtained.

The impedance properties of the plurality types of boundary acoustic wave devices thus obtained were measured, and in the same manner as described above, the impedance ratios were obtained.

Fig. 10 is a view showing the relationship between the impedance ratio of the spurious signals obtained as described above and the depth of the groove 3b, that is, the depth of the recess portion. As can be seen from Fig. 10, it is understood that the impedance ratio of the spurious signals is improved to 10 dB or less when the depth of recess portion is 0.05 λ or more and is further improved to 5 dB or less when the depth of the recess portion is 0.6 λ or more. Hence, the depth of the recess portion is preferably 0.05 λ or more and more preferably 0.6 λ or more.

Fig. 11 is a view showing the relationship between the impedance ratio of the spurious signals and the pitch between the grooves 3b. As can be seen from Fig. 11, when the pitch between the grooves 3b is set to 1 λ or more, it is understood that the impedance ratio of the spurious signals can be improved to 10 dB or less. Hence, preferably, the pitch between the grooves 3b is desirably set to 1 λ or more.

In addition, it is also confirmed that even when the

angle formed between the groove 3b and the extending direction of the electrode finger of the IDT is set to 0° or 90°, by forming the grooves 3b so as to have a depth of 0.05 λ or more, the impedance ratio of the spurious signals can be improved.

In this embodiment, the grooves 3b are disposed in parallel to each other to form a predetermined angle with the extending direction of the electrode fingers; however, as shown by a schematic perspective view of Fig. 12, in addition to the grooves 3b, grooves 3c may be disposed in the upper surface 3a of the SiO_2 film 3 so as to intersect the grooves 3b. Also in the case described above, when the depths of the grooves 3b and 3c are set to 0.05 λ or more, it is confirmed that the impedance ratio of the spurious signals can be improved as described above.

In Figs. 1 and 12, in the SiO_2 film, that is, in the upper surface of the first medium, the grooves 3b or the grooves 3b and 3c are formed, instead of the linear grooves, curved grooves or grooves having another shape may also be formed. That is, the irregularities in the present invention are not limited to grooves which are disposed in parallel and which linearly extend.

In addition, in forming the recess portions, when the depth of the recess portion is set to $\lambda s/4 \times \sin \theta s$ in which the spurious wavelength and the angle of the above spurious

mode incident on the upper surface 3a of the SiO_2 film 3 are represented by λs and θs, respectively, the phase of the spurious signals reflected at the recess portion 3b is opposite to the phase reflected at the upper surface 3a, so that the above two phases counteract each other. Hence, it is believed that the spurious signals received by the IDT 4 can be more effectively suppressed.

In forming the recess portions described above, many grooves 3b are preferably formed; however, when at least one groove 3b is formed, the effect as described above can also be obtained. In addition, instead of the recess portions, protrusion portions in the form of dots may be provided, and the recess portions and/or the protrusion portions may both be provided.

(Second Embodiment)

A boundary acoustic wave device of the second embodiment has the structure similar to that of the boundary acoustic wave device 1 of the first embodiment. Hence, description of the boundary acoustic wave device of the second embodiment will be omitted, and whenever necessary, the description of the boundary acoustic wave device of the first embodiment may be used instead. Points of the boundary acoustic wave device of the second embodiment different from the first embodiment are as follows, that is, (1) grooves are not provided in the upper surface of the

SiO_2 film 3, and (2) the thickness of the SiO_2 film 3 is set to 7 λ or more.

That is, in the first embodiment, the irregularities are provided by forming the grooves 3b or the grooves 3b and 3c, and as a result, the spurious signals are suppressed. In contrast to the first embodiment, in the boundary acoustic wave device of the second embodiment, since the thickness of the SiO_2 film 3 is set to 7 λ or more, the spurious signals are suppressed. This suppression will be described with reference to particular experimental examples.

The boundary acoustic wave device 1 was formed in the same manner as that of the experimental example of the first embodiment. However, the irregularities were not provided in the surface of the SiO_2 film 3, and the thickness of the SiO_2 film 3 was variously changed. The relationship between the thicknesses of plural types of boundary acoustic wave devices thus obtained and the impedance ratio of the above spurious mode is shown in Fig. 13.

As can be seen from Fig. 13, it is understood that when the thickness of the SiO_2 film is increased to 7 λ or more, the impedance ratio of the spurious mode can be decreased to 5 dB or less.

In the boundary acoustic wave device of the second embodiment, it is believed that since the thickness of the SiO_2 film 3, which is the second medium layer having a

relatively low sound velocity and in which an acoustic wave formed into spurious signals is confined, is sufficiently increased, the spurious signals caused by the above acoustic wave can be suppressed.

In addition, more preferably, in the boundary acoustic wave device 1 of the first embodiment, that is, in the structure in which the recess portions and/or the protrusion portions are provided for the upper surface of the SiO_2 film, when the thickness of the SiO_2 film is increased as is the case of the second embodiment, the above spurious signals can be more effectively suppressed. Hence, preferably, a boundary acoustic wave device is formed having spurious suppression structures according to the first and the second embodiments.

Fig. 14 is a schematic front cross-sectional view showing a modified example of a boundary acoustic wave device of the present invention.

In the boundary acoustic wave device 1 of the first embodiment, the recess portions are formed by the formation of the grooves 3b in the upper surface of the SiO_2 film; however, in the case described above, an external layer material 11 may be formed so as to cover the above recess portions. When the exterior layer material 11 is formed, although a surface 11a of the exterior layer material 11 is flat, since the irregularities are provided in the upper

surface 3a of the SiO_2 film 3 functioning as the second medium layer, the spurious signals can be effectively suppressed as is the case of the first embodiment. As the exterior layer material 11, for example, a material such as AlN may be optionally used.

By the formation of the exterior layer material 11, the mechanical strength of the boundary acoustic wave device can be improved, or the penetration of corrosive gases can be prevented. That is, since the exterior layer material 11 may function as a protective layer as described above, an insulating material, such as titanium oxide, aluminum nitride, or aluminum oxide, or a metal material such as Au, Al, or W may be used for forming the exterior layer material 11.

In addition, by the formation of the exterior layer material 11, in the case in which the electroacoustic impedance of SiO_2 used as the second medium layer and that of the exterior layer material 11 are significantly different from each other, between the boundary formed by the first medium layer and the exterior layer material 11 and the boundary along which the boundary acoustic wave propagates, the spurious mode is confined and propagates as is the case of a conventional boundary acoustic wave device. However, even in the case described above, when the recess portions and/or the protrusion portions are formed according

to the first embodiment, the spurious mode can e suppressed.

Furthermore, in the present invention, between the first and the second medium layers, a third medium layer having a sound velocity lower than that of the first and the second medium layers may be provided so as to be used as the boundary layer. In this case, electrodes such as an IDT may be formed between the first and the third medium layers. As described above, also in the structure having the third medium layer, a spurious mode is generated propagating in the first or the second medium layer at the same time when the boundary acoustic wave is driven; however, the spurious mode can be suppressed by the formation of the first medium layer in the same manner as that of the first or the second embodiment. Also in the case in which third and fourth medium layers are formed between the first and the second medium layers, when irregularities are formed at any one of the boundaries between the layers, the spurious mode can be suppressed.

In the first and the second embodiments, the IDT 4 and the reflectors 5 and 6 are formed using Au; however, an electrode material of the boundary acoustic wave device is not limited to Au, and for example, Ag, Cu, or Al may also be used. In addition, in order to improve the adhesion and electrical power resistance of the electrode, a thin layer composed of Ti, Cr, or NiCr may be provided on the electrode

layer. In addition, besides resonators, the present invention may be applied to a lateral coupling type filter, a longitudinal coupling type filter composed of at least two IDTs and reflectors provided outside the IDTs, a ladder type filter, and a lattice type filter.

In addition, as a material forming the first and the second medium layers, besides $LiNbO_3$ and SiO_2, various piezoelectric materials such as $LiTaO_3$, $Li_2B_4O_7$, quartz, and titanate zirconate lead-based ceramic, and various dielectric materials such as glass and sapphire may also be used.

Industrial Applicability

According to the boundary acoustic wave device of the first aspect of the present invention, since the first medium layer having a relatively low sound velocity has a thickness of 7 λ or more, as can be seen from the above-described experimental example, spurious signals can be effectively suppressed which propagates between the boundary surface along which the boundary acoustic wave propagates and the surface of the second medium layer opposite to the boundary surface, and hence a boundary acoustic wave device can be provided having superior resonance properties and filter properties.

According to the second aspect of the present invention,

since the structure for scattering an acoustic wave is provided for at least one surface of the first and the second medium layers opposite to the boundary surface along which the boundary acoustic wave propagates, unwanted spurious signals caused by the acoustic wave can be effectively suppressed, and as a result, superior resonance properties and filter properties can be obtained.

Since the boundary acoustic wave devices according to the first and the second aspects of the present invention use a boundary acoustic wave between the first and the second medium layers, a complicated package having a cavity portion is not required, and production can be performed at a reasonable cost. In addition, compared to a surface acoustic wave device, miniaturization and reduction in weight can be achieved, and hence a compact acoustic wave device can be provided in which high density mounting can be suitably performed.

According to the second aspect of the present invention, when the structure for scattering an acoustic wave is provided for the second medium layer, the spurious mode in the second medium layer having a relatively low sound velocity, through which spurious signals are liable to propagate, can be effective suppressed.

When the structure for scattering an acoustic wave is formed of recess portions and/or protrusion portions

provided on the surface of the medium layer opposite to the surface along which the boundary acoustic wave propagates, by the recess portions and/or the protrusion portions, the spurious mode can be reliably scattered.

When the depth of the irregularities described above is 0.05 λ or more, or when the pitch between the recess portions and/or the protrusion portions is 1 λ or more, the spurious signals can be more effectively suppressed.

In the second aspect of the present invention, when the distance between the surface along which the boundary acoustic wave propagates and the surface for which the structure for scattering an acoustic wave is provided is 7 λ or less, since the thickness of the medium layer provided with the structure for scattering an acoustic wave is relatively thin, the spurious signals cannot be suppressed by the thickness of the medium layer; however, by providing the recess portions and/or the protrusion portions according to the second aspect of the present invention, the spurious signals can be effectively suppressed.

When the exterior layer material is further provided so as to cover the recess portions and/or the protrusion portions, by the presence of the exterior material layer, the mechanical strength of the boundary acoustic wave device can be increased, and/or the electrical power resistance can be improved.